SELECTION OF ELECTRIC MOTORS FOR FARM USE

Outline of Discussion

by

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I WHAT MACHINE CHARACTERISTICS DETERMINE MOTOR REQUIREMENTS?

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V HOW ARE MOTORS STARTED AND CONTROLLED?

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I WHAT MACHINE CHARACTERISTICS DETERMINE MOTOR REQUIREMENTS?

Farm machinery and equipment ordinarily turned by hand can be operated with a small electric motor at a cost range of 1¢ to 5¢ per hour for electricity. The small motor may be put to a practically unlimited number of uses on the farm to bring about a saving in time and labor and to reduce investment in new equipment. Hand labor cannot compete economically with low cost electric power.

To understand properly how motors meet operating conditions, it is necessary to divide each load into three parts. Each of these parts may vary separately and independently of each other over a wide range. These parts are designated as (a) starting load, (b) acceleration load, and (c) full speed load. Before selecting the motor for any particular use, the three loads which it is to handle should first be understood.

(A) Starting Loads

Some driven machines start with practically no load, and the full load develops only when full speed is reached. With other machines, there is some load when starting, but the load increases as the speed increases. In still other cases, the machine starts under full load. Examples of machines having each of these characteristics are:

1. No starting load -	Fan, Tool Grinder
2. Some starting load -	Ensilage cutter
3. Full load at start -	Piston type water pumps, cream separator.

(B) Acceleration Loads

When started, the machine or tool must be brought up to full speed. This is the accelerating load of the machine and is determined by the friction between the working parts, the inertia of the working parts, and the increased work done by the machine as the speed increases. A cream separator and a heavy fly wheel are hard to start. They are excellent examples of great inertia. In general, heavy objects have greater inertia or resistance to change in speed than light objects. In the case of a blower fan, the load increases as speed increases because more air is being moved.

(C) Full Speed Loads

This refers to the load of the machines on the motor after it has reached full speed. In addition, temporary overloading of the motor must also be included. The motors on such machines as ensilage cutters, hammer mills, and hay balers, may be subject to frequent and rather large temporary overloads.

TORQUE

Turning effort is usually expressed in terms of "torque." Torque is measured in foot pounds of work required to rotate a load. It is also used to measure the power of the motor in pulling on the belt. Engineers, mechanics, and electricians divide the three torque loads discussed under A, B, and C above as follows:

Starting Torque -	Turning effort required to start rotating a load.
Pull-up Torque -	Turning effort to bring the load up to the proper operating speed after it is started.
Break-down Torque -	The size of load that will reduce motor speed and eventually stall the motor.

The size of motor required to operate any machine depends on the three types of lo ads and the duration of the maximum load. Since the types of electric motors generally available have different operating characteristics, the type must be matched to the load to obtain satisfactory operation.

Most farmers have only single phase electric service. Consequently the following discussion will cover single phase motors only. These motors are made in several designs, but only two of these designs are particularly well adapted to general farm use. They are the capacitor start and the repulsion start induction run motors. When both the machine and motor characteristics are known, the proper size and type of motor can be selected.

II WHAT ARE THE OPERATING CHARACTERISTICS OF SPLIT PHASE, CAPACITOR AND REPULSION INDUCTION MOTORS?

The three types of single phase motors best suited for farm use are (1) split phase induction motor, (2) capacitor-start induction motor, and (3) repulsion-start induction run motor. There are several other

types of single phase motor, but they are not generally as desirable as the three listed above.

Split Phase Induction Motors

A split phase motor is the lowest in first cost of the three types of motors. Its operating characteristics are the least desirable of the three. Its greatest starting torque is approximately 230 percent of its full load torque, and its pull-up torque is approximately 200 percent of full load torque. This is very small when compared to the starting and pull-up loads of many farm machines. Consequently the split phase motor should not be used on machines that are hard to start or to bring up to full speed.

The split phase motor has a breakdown torque of approximately 230 percent of its rated full speed torque. This type motor requires a relatively large amount of current to start and come up to full speed. The starting current may be 7 to 9 times the full load current. This motor is not made in sizes over one-half horsepower because of the excessive starting and accelerating current.

This high starting current is undesirable in many situations because very large wires are necessary if the motor is to have its full, though limited, starting ability. When improperly installed, or when used on circuits in buildings with too small wiring, it causes lights to flicker when starting. You will note in Table I that the starting current required by this motor is 2½ times that of a repulsion start induction motor, yet it has slightly less than one-half the starting torque.

Capacitor-Start Induction Run Motors

Capacitor start, induction motors are somewhat more expensive than split phase motors. The capacitor type motor can be distinguished

"For the (Connecticut) farmers, there isn't any doubt that the help of boys and girls is necessary if they are going to keep up their high production. There isn't anybody else to do the job."--P. L. Putnam, Connecticut State Supervisor.

"School youth may be needed in the fall harvest. Excuses from classes will depend upon the willingness of the local school authorities, says Mr. Earl Little, of the State board of education."--New Hampshire EFL news letter.

"Farmers should be informed that unless boys are hired now, they may find other employment and thus be lost for the entire summer for farm work."--South Dakota news letter.

MANHATTAN ANGLE ON SAFETY

Benjamin Towne, farm adviser at Stuyvesant High School in New York City, has become particularly interested in farm safety through his work in selecting boys for summer farm work in cooperation with New York's farm cadet program. And speaking of selection, Towne writes us that only 50 of the 100 Stuyvesant High boys who wanted to do farm work "will be allowed to leave for farm work this summer."

But on the subject of safety, Towne is especially anxious to see more educational work done with farmers and farm workers toward preventing accidents. To this end he has worked up two mimeographed sheets listing do's and don'ts for the Stuyvesant boys who leave for the farm.

That reminds me to remind you that July 20 to 26 is National Farm Safety Week. Maybe you'll agree with me that every week really ought to be farm safety week.

BRIEFLY SPEAKING....

Reports from many scattered States certainly indicate that many boys and girls will be seeking farm work this summer....Some county people in Pennsylvania, however, say that boys sometime want too high wages as live-ins....Fifty high school boys in Sheboygan County, Wisconsin, had signed up for pea harvesting in May. They took the place of foreign workers....New Hampshire farmers are ordering Boston boys as live-ins....Recruiting for Connecticut tobacco camps in Pennsylvania this spring seems to have been no problem, with more than enough youth wanting to go.

Arrangements have been made in Jasper County, Georgia, for school children to pick up peach drops, with school teachers as supervisors....Essex County, New Jersey, reports, "a lot of fine boys and girls are being signed up" to go to Vermont as live-ins.

This New Jersey-Vermont cooperation seems to have worked out very well.... Reports during May from Iowa say many youth were seeking farm work. With the disastrous crop losses in that State we wonder if youngsters will get much farm work this summer.

SUGGESTIONS FOR SUPERVISORS

In New York, VFV Supervisor Jack Weaver has prepared an instruction manual for county supervisors. What does it include? Well, listed are items on school program adjustments, farm work permits and employment certificates, day-haul services, responsibility of the various services involved in the Farm Cadet program, duties of supervisors, insurance, accidents and sickness, and travel accounts for supervisors.

You'll be interested to know that 38 counties in New York will have special Farm Cadet supervisors this year--meaning that live-ins placed in those counties will get the attention of one person whose sole responsiblity is to help them make adjustments and do a successful job. The large percentage of boys placed are big-city youth, chiefly from the New York City area, although New York farm labor assistants will lay more stress this year on placing their own city boys on farms within their own counties.

At any rate, it appears that New York's program for placing urban boys in summer farm jobs may be here to stay. State funds this year pay for three-fourths of the program's expenses, indicating strong State concern for the program.

A TRIP TO VIRGINIA

I had an interesting visit with D. A. Tucker, Virginia's State farm labor supervisor, in the Norfolk strawberry area during May. Several Midwestern States are on our field schedules for July, but definite plans have not yet been made.

Sincerely yours,

Irvin H. Schmitt

Irvin H. Schmitt, Chief
Victory Farm Volunteers Division
Extension Farm Labor Program

(Copy to Directors, Editors,
State Supervisors)

Other types of Motors

There are several other types of motors, none of which are as adaptable to general farm use as the three previously described. The universal motor is probably most commonly used. It gets its name from its adaptability to operate on either alternating or direct current. It depends on its load to control its speed, and consequently has very poor speed regulation. Its main application is for small household appliances, such as a food mixer or vacuum cleaner. It is not recommended for general farm use.

Fractional Horsepower Motors

Fractional horsepower motors are those rated at less than one horsepower. Such motors are made in split phase, capacitor, and repulsion-induction types. They can be operated on 115 volts, but 230 volts give better operating results for one-half horsepower or larger sizes. Wiring changes within the motor must be made to change from 115 volts to 230 volts, or vice versa.

Many fractional horsepower motors are permanently attached to the machines they operate because of the frequency of using the machines. When several machines requiring a small motor are to be operated infrequently, one motor can often be used for all. In such cases, both motor and machine should have attachments that permit easy, quick, firm mounting, and easy, quick dismounting of the motor. A motor used in this way is known as a portable motor.

Integral Horsepower Motors

Integral horsepower motors are of one horsepower or larger size. They may be obtained in 1, $1\frac{1}{2}$, 2, 3, 5, $7\frac{1}{2}$ or 10 horsepower sizes. Split phase motors are not made in these sizes, but both capacitor and

repulsion induction motors are generally available. As previously stated, some power suppliers may not permit the use of $7\frac{1}{2}$ or 10 horsepower motors on their lines. When necessary, the larger motors can also be made portable by attaching them to a two-wheeled cart.

III WHAT KIND OF BEARINGS DO MOTORS HAVE?

A motor has a uniform turning movement. Because of this, there is little shock or vibration on the motor bearings. If a motor is properly mounted on a rigid support, most of the wear on the bearings will be that due to the weight of the rotating part and the pressure due to belt tension and motor torque.

A bearing is designed for a definite load or pressure on its surface. If this load is exceeded, rapid wear results. A belt that is too tight will overload a bearing and cause abnormal wear and undue heating. For this reason, a belt should be just tight enough to prevent slipping.

Both sleeve and ball types of bearing are used. Ball bearings are easier to keep properly lubricated and require less attention. They are made of high grade steel, while sleeve bearings are made of brass, bronze, or babbitt. Ball bearing motors cost more than sleeve bearing motors, but this additional cost is offset by the less attention they require.

Bearings are not only designed for definite loads, but are designed to take loads in only one direction. Consequently a motor designed for horizontal mounting should not be mounted with the shaft vertical nor positions which are extremely off level. Motors for vertical mountings must have a thrust bearing at one end of the shaft to support the armature. Vertical motors are normally built with ball bearings because of lubrication problems on sleeve bearings when mounted in a vertical position.

Occasions will sometimes arise when a horizontal motor must be mounted overhead in an upside down position, or possibly on its side with the base mounted on a vertical wall. When this is necessary, the motor end brackets or bells must be removed and revolved so the bearing oil reservoirs are in their normal position below the bearings. This change is very important, as otherwise the oil can drain out leaving the bearing without lubrication.

IV HOW ARE MOTORS PROTECTED FROM EXCESSIVE CURRENT?

Electric motors are capable of taking great overloads without damage for short periods of time. However, if overloading continues, the motor will overheat and will be damaged. This is due to excessive heating of the windings in the motor and the destruction of the insulation. Consequently, electric motors should have protective devices to limit the current they can draw and to stop them when they begin to overheat.

There are four general methods of motor protection. These are (1) protection against short circuits and large overloads; (2) protection against long, continuous overload; (3) protection against low voltage; and (4) thermal protection against heating that accompanies the first three conditions.

Motors are usually protected from short circuits and large overloads, that would result in stalling, by fuses or circuit breakers. Motors draw a much higher starting than operating current, and such fuses or circuit breakers must have a current carrying capacity of several times the normal full load capacity of the motor. As a result, these devices do not protect against moderate, but continuous, overloads.

Continuous Overload Protection

All motors should be protected against moderate, continuous overloads. When motors become overloaded, excessive heat is generated proportional to the overload. Devices for this type of protection shut off the motor when the protective device reaches a certain temperature. The greater the overload, the shorter the time required for sufficient heat to develop to stop the motor. These devices are made on several principles by different manufacturers, but any Underwriters' Laboratories approved control should be satisfactory. When an overload switch opens, the motor cannot be restarted until the control has had time to cool. If a motor has heated, it can be cooled by <u>running it without load</u> after the starting device has been reclosed.

Low Voltage Protection

An electric motor is designed and built to operate at its rated voltage. When the voltage is too low, the motor will either fail to start, will not come up to its rated speed after starting, or will not handle its full load without overheating. Under these conditions a motor will draw more current than it is designed to use. This results in overheating and damage to the motor. The insulation of the windings may actually burn out. Most motors are designed to run at 72^{0} F. above the temperature around them. (Note: Permissible increase in motor temperature is shown as 40° C. on the name plate of the motor. This is the equivalent of 72° F.)

When the motor is in operation, it warms up but no damage results as long as the temperature does not exceed the 72° F. rise permitted. If allowed to continue to heat, the insulation on the wires will

eventually be damaged and may smoke and burst into flame. If your hand can be held on a motor without discomfort, the temperature is not too high.

To protect motors from low voltage damage, a switch or starting box having a low-voltage cut-out is often used. Should the voltage fall below a point set by the manufacturer, the control would automatically stop the motor. The switch will not remain closed when reset until the low voltage condition has been corrected. Low voltage protection is not generally used on fractional horsepower motors.

Thermal Motor Protection

Some manufacturers place a thermal switch or thermostat in the motor when it is assembled. These switches are set to open, thus cutting off the current whenever the motor becomes to warrm for safety. In many cases they are made to close the circuit automatically when the motor cools off. In other designs, they must be reset by hand after the motor cools down. This type of control operates entirely independent of other motor controls installed as a part of the wiring system or specifically for the motor.

V MOTOR STARTERS AND CONTROLS

Regulations and rules established by the National Electrical Code for starting equipment should be met. The motor controller or switch should have a horsepower rating not lower than the horsepower rating of the motor. However, there are a few exceptions to this rule. For example: portable motors one-fourth horsepower or smaller may be started and stopped by connecting or disconnecting an extension cord to a convenience outlet; for a two horsepower or smaller stationary motor, the controller may be a general use switch having

an ampere rating of at least twice the full load current rating of the motor.

To sum up the above requirements, a motor above one-fourth horsepower rating must have an approved type starting switch of rated capacity equal to the motor on which it is to be used. This switch must be mounted within sight of the motor and within 50 feet of the motor.

There are three general classes of starting switches. They are:

1 - Manual across-the-line starter
2 - Magnetic across-the-line starter
3 - Manual or magnetic start, current limiting control

A manual control must be operated at the switch, wherever it is located. A magnetic control may be operated at a remote point by using a push button switch and an extension cable, long enough to reach the point where motor control is desired. This is much safer than the manually operated control because the push button switch can be placed in a location convenient to the operator.

The magnetic across-the-line starter is most commonly used on farm motors larger than one horsepower. This device does not operate on momentary overloads such as the high starting current, but will protect the motor from sustained overload. The motor dealer should supply the proper controls for the motors he sells.

The frames of all motors and the frames of their starting controls should be grounded. This can be done by using a special ground rod connected to the motor frame by a continuous bare copper wire of sufficient size to carry more current than the fuse in the circuit. This ground wire should be bonded to or interconnected with the ser-

vice ground at the main service entrance equipment. The motor frame can also be grounded through the farmstead wiring, if the wiring is a grounded secondary system. This requires a three-wire cable, the motor frame being grounded to the white wire.

VI WHAT ARE THE MOST COMMON MOTOR SPEEDS AND HOW IS DIRECTION OF MOTOR ROTATION CHANGED?

The most common motor speed is 1750 rpm. The next most generally available speeds are 1160 and 3500 rpm. However, motors with these latter speeds are somewhat more expensive to purchase because they are manufactured in smaller quantities.

Main pulleys on farm machines may rotate in different directions. The same motor is frequently used to drive several machines. If the motor cannot be properly located, it will be necessary to change the direction of the rotation of the motor. This can be done by the operator, but it requires a few minutes time and a knowledge of how to change the wires in the motor.

The split phase and capacitor motors are reversed in direction by reversing the starting winding leads. Wiring changes are shown on diagrams under the cover plage where the wires attach to the motor or on tags attached to each new motor. The repulsion start induction motor is reversed by shifting the brushes in the direction of desired rotation. Marks inside the motor show the proper brush holder location for the desired direction of rotation. Manufacturers supply complete instructions with each type of motor for reversing direction of rotation.

AVERAGE STARTING TORQUE, PULL-UP TORQUE, BREAK DOWN TORQUE, EFFICIENCY AND THE MAXIMUM STARTING CURRENT OF SOME SINGLE PHASE MOTORS

TABLE I

	REPULSION START INDUCTION	CAPACITOR START INDUCTION	SPLIT PHASE START INDUCTION
**FRACTIONAL HORSEPOWER MOTORS			
Starting Torque	550%	435%	230%
Pull-up Torque	225%	250%	200%
Break-down Torque	265%	265%	230%
Efficiency	66%	65%	65%
***Maximum Starting Current(Percent full load current)	200 to 400%	600 to 700%	700 to 900%
*INTEGRAL HORSEPOWER MOTORS			
Starting Torque	400 to 450%	250%	
Pull-up Torque	200%	200%	
Break-down Torque	235%	210%	
Efficiency	81%	78%	
***Maximum Starting Current(Percent full load current)	200 to 400%	600 to 700%	

*Taken from information on 5 HP single phase motors published by Century Electric Co., St. Louis, Missouri

**Taken from information published by Century Motor Co.

***Taken from "Electrical Engineering" - 1939 issue - by E. E. Kimberly

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